STRATFORD / AVON RIVER
ENVIRONMENTAL MANAGEMENT PROJECT

STRATFORD/AVON RIVER ENVIRONMENTAL
MANAGEMENT PROJECT

ALTERNATIVE METHODS OF REDUCING AQUATIC PLANT GROWTH IN THE AVON RIVER

Technical Report S-7

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PREFACE

This report is one of a series of technical reports resulting from work undertaken as part of the Stratford-Avon River Environmental Management Project (S.A.R.E.M.P.).

This two-year project was initiated in April 1980, at the request of the City of Stratford. The S.A.R.E.M.P is funded entirely by the Ontario Ministry of the Environment. The purpose of the project is to provide a comprehensive water quality management strategy for the Avon River basin. In order to accomplish this, considerable investigation, monitoring and analysis has taken place. The outcome of these investigations and field demonstrations will be a documented strategy outlining the program and implementation mechanisms most effective in resolving the water quality problems now facing residents of the basin. The project is assessing urban, rural and in-stream management mechanisms for improving water quality.

This report results directly from the aforementioned investigations. It is meant to be technical in nature and not a statement of policy or program direction. Observations and conclusions are those of the authors and do not necessarily reflect the attitudes or philosophy of all agencies and individuals affiliated with the project. In certain cases the results presented are interim in nature and should not be taken as definitive until such time as additional support data are collected.

Reference to equipment, brand names or supplies in this publication is not to be interpreted as an endorsement of that particular product or supplier.

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ABSTRACT

High densities of aquatic plant growth have the potential to cause dissolved oxygen depletion due to their proportionately high respiratory demand at night. Nuisance plant growths can also degrade the appearance of a stream and can produce obnoxious odours when plant material dies and decays. A variety of methods can be used to control such plant growths. The advantages and disadvantages of several of these were examined as part of the Stratford-Avon River Environmental Management Study, with consideration being given to each measure's potential impacts on the stream environment and on water use, as well as to likely costs of implementation.

The most promising measure examined was shading of the stream with bankside plantations of trees. Other methods considered less feasible for one or more reasons were mechanical and manual cropping, injection of herbicides into the stream, increased turbidity, and channelization. Combinations of measures were not examined but are potentially valid. An important method, limitation of the nutrients which support plant growth, will be addressed in another report in this technical report series.

1. INTRODUCTION

High aquatic biomass densities have the potential to cause dissolved oxygen depletion due to their proportionately high respiratory demand at night. Nuisance plant growths can also degrade the appearance of a stream, and can produce obnoxious odours when plant material dies and decays.

The stream bed mapping done in conjunction with the physical surveys (SAREMP Technical Report No. S-2) indicated that most of the Avon River below John Street (Station 6) exhibited substrate types hospitable for aquatic plant growth. The nuisance alga *Cladophora* prefers rocky substrates, especially limestones, while the rooted aquatic *Potamogeton* is found in greatest abundance on coarse substrates such as sands and gravels (Painter and Walker, 1981). In addition to a favourable substrate, light and nutrient availability also foster luxurious growths of these species.

This report provides information on the extent of aquatic biomass growth in the Avon River and discusses the feasibility of various methods of controlling nuisance growths of these plants; such as channelization, light reduction, chemical control, and plant removal.

There are various methods available to control the growth of aquatic plants. One important method, limitation of nutrients supporting plant growth, will be addressed in another report in this technical report series . The focus of this report will therefore be on methods other than nutrient limitation.

2. METHODS

Of the five methods of aquatic plant control examined, two were aimed at preventing or controlling the growth of plants in the river, while the remaining three were aimed at reducing plant densities once they had achieved nuisance levels. Results of the investigations into each of these control methods are presented separately below. A map of the Avon River basin is shown in Figure 1. Also given in this figure are the numerical reach and station designations which are used in subsequent sections of this report.

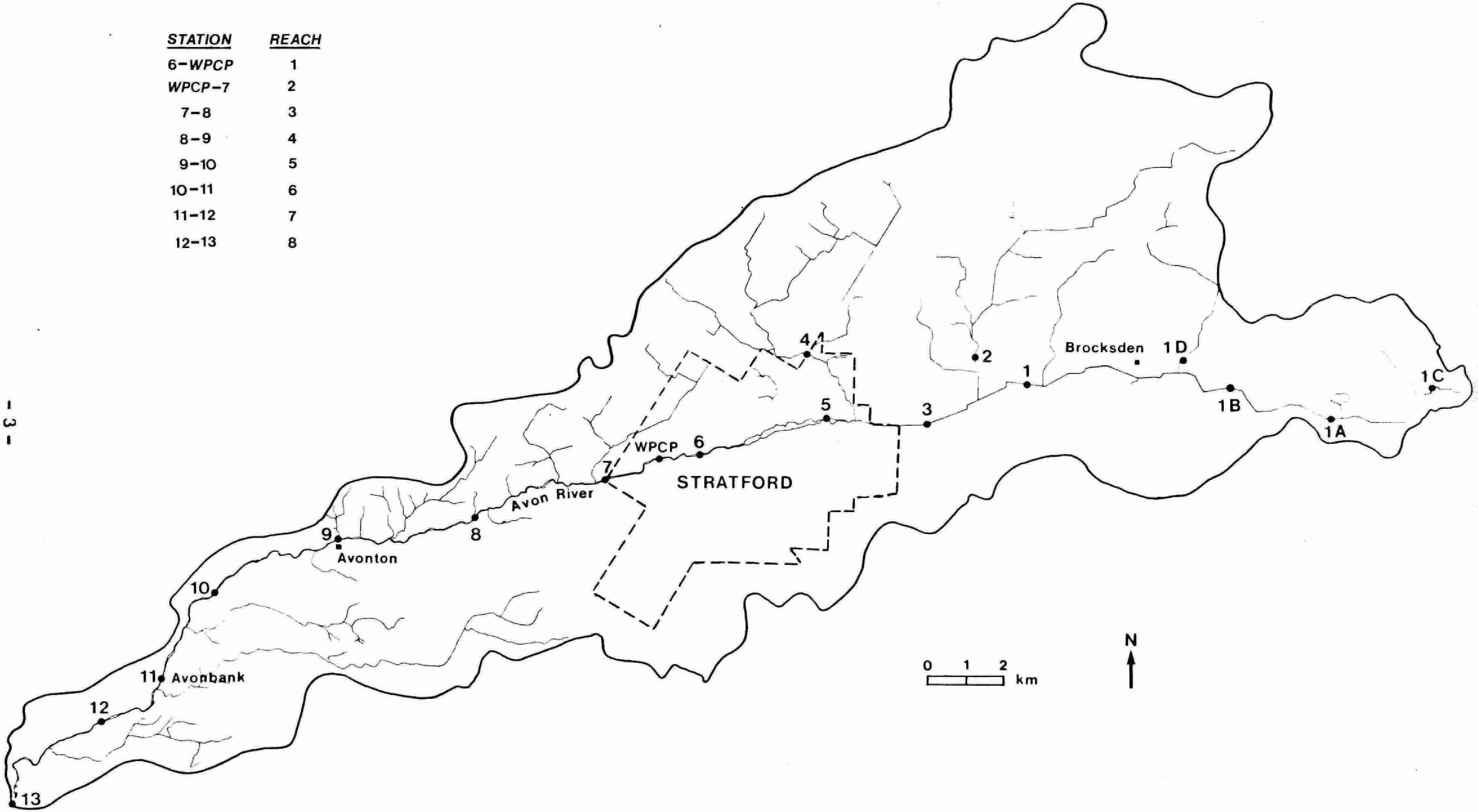
2.1 Channelization (Habitat Modification)

Habitat modification involves altering the existing stream environment so that it becomes unsuitable for the growth of aquatic plants. Unsuitable habitat can be achieved by channelizing (excavating) the river to obtain water depths in excess of one metre. Wetzel and his colleagues showed that the one metre depth caused sufficient light extinction to prevent substantial growth of plants (Wetzel et al., 1981).

Existing depth profiles of the Avon River below the City of Stratford were determined during surveys conducted in 1980 and 1981 by staff of the Water Resources Branch, MOE (see SAREMP Technical Report No. S-2, Bacchus, 1981). These profiles were analyzed to identify those reaches of the river less than 1 m deep. Resulting information was used to estimate the volume of river bank and bed which would have to be dredged to achieve the 1 m depth. If this alternative were to be undertaken without an accompanying increase in river flow, the width of the channelized river sections would have to be decreased. New river widths were also calculated under this assumption.

2.2 Light Reduction

A second method of achieving permanent control of the aquatic plant growth is to reduce the amount of light penetrating to the river bed. There are two basic approaches to achieving this; increasing stream turbidity, and stream shading. The first technique, increasing turbidity, causes both aesthetic and water use problems, and is therefore not a desirable alternative.



STATION	REACH
6-WPCP	1
WPCP-7	2
7-8	3
8-9	4
9-10	5
10-11	6
11-12	7
12-13	8

Figure 1 Monitoring Stations in the Avon River watershed

The second technique involves shading the stream by planting trees along the bank of the river. The impact of stream shading upon the penetration of light to the stream bed was assessed at station 8 in June, 1980. These data were used in conjunction with the ECOL1 model to simulate the impact of shading on the plant growth in a reach of the Avon River.

An assessment of potential sites where the river valley profile and river width are suitable for planting of trees was also carried out using aerial photographs. This information, as well as the information derived from the site-specific investigations and literature review, was applied to the entire basin below the City of Stratford.

2.3 Chemical Control

An alternative to permanent control of plant growth through physical alteration of the environment is temporary control of plants with a herbicide. Information on chemical techniques to control plant growth was compiled during the Grand River Basin Water Management Study (Willson et al. 1981). Conclusions from these studies were evaluated relative to the Avon River situation and estimated costs pro-rated accordingly.

2.4 Removal of Nuisance Plant Growth

The final alternative addressed in this report is control of nuisance plant growth through cropping and removal of plant material from the river by manual or mechanical methods.

An experiment to assess the feasibility of manual harvesting was carried out in the Speed River in 1980 as part of the Grand River Basin Water Management Study. The area cropped had a 60-70% coverage of Cladophora; algal filaments in the area ranged in length from 0.5 to 1 m. Cropping was carried out by two people working at about a 75% cropping efficiency.

Information on mechanical and manual techniques to control plant growth can also be found in Willson et al. 1981. Conclusions from these studies were evaluated relative to the Avon River situation. Estimated volumes of plant material and removal costs were pro-rated accordingly.

3. RESULTS

3.1 Channelization (Habitat Modification)

Examination of the depth profiles of the Avon River (Bacchus, 1981) indicates that the entire river below the City of Stratford would require channelization if a minimum water depth of 1 m were to be achieved. Table I gives the estimated volume of dredging spoils which would be produced if this alternative were undertaken. The data presented in the table are based on the assumption that the river width is simultaneously decreased, (i.e. the existing cross-sectional area is maintained) so no associated increase in flow would be required to provide the desired 1 m water depth.

TABLE I: ESTIMATED VOLUME OF DREDGE SPOILS PRODUCED BY CHANNELIZING THE AVON RIVER TO A MINIMUM DEPTH OF ONE METER

Reach	Existing Width (m)	Existing Length (m)	Existing Depth (m)	Required Width with 1 m depth (m)	Spoil Volume (m^3)
1	9.603	1000	0.36	3.423	2200
2	11.817	1216	0.30	3.583	3000
3	14.309	3370	0.30	4.234	10200
4	16.043	2870	0.25	4.083	8600
5	19.912	3074	0.23	4.596	10800
6	16.562	2288	0.23	3.793	6700
7	20.309	1615	0.17	3.369	4700
8	17.215	3314	0.17	2.944	8000

Sediment samples obtained on August 6, 1980, along the Avon River (Figures 2-4) indicate that for some elements, the river sediments are moderately to heavily polluted (MOE Hamilton Harbour Study, 1977; Table III). This fact adds to the problem of disposal as care would have to be taken to ensure that contamination of the environment does not occur due to release of the polluting substances from the dredge spoils.

Dredge spoils could be used as fill that would be required to re-structure of the new dredged channel. A potential drawback to channel restructuring is bank failure under certain flow conditions and an eventual return to the original shallow channel profile.

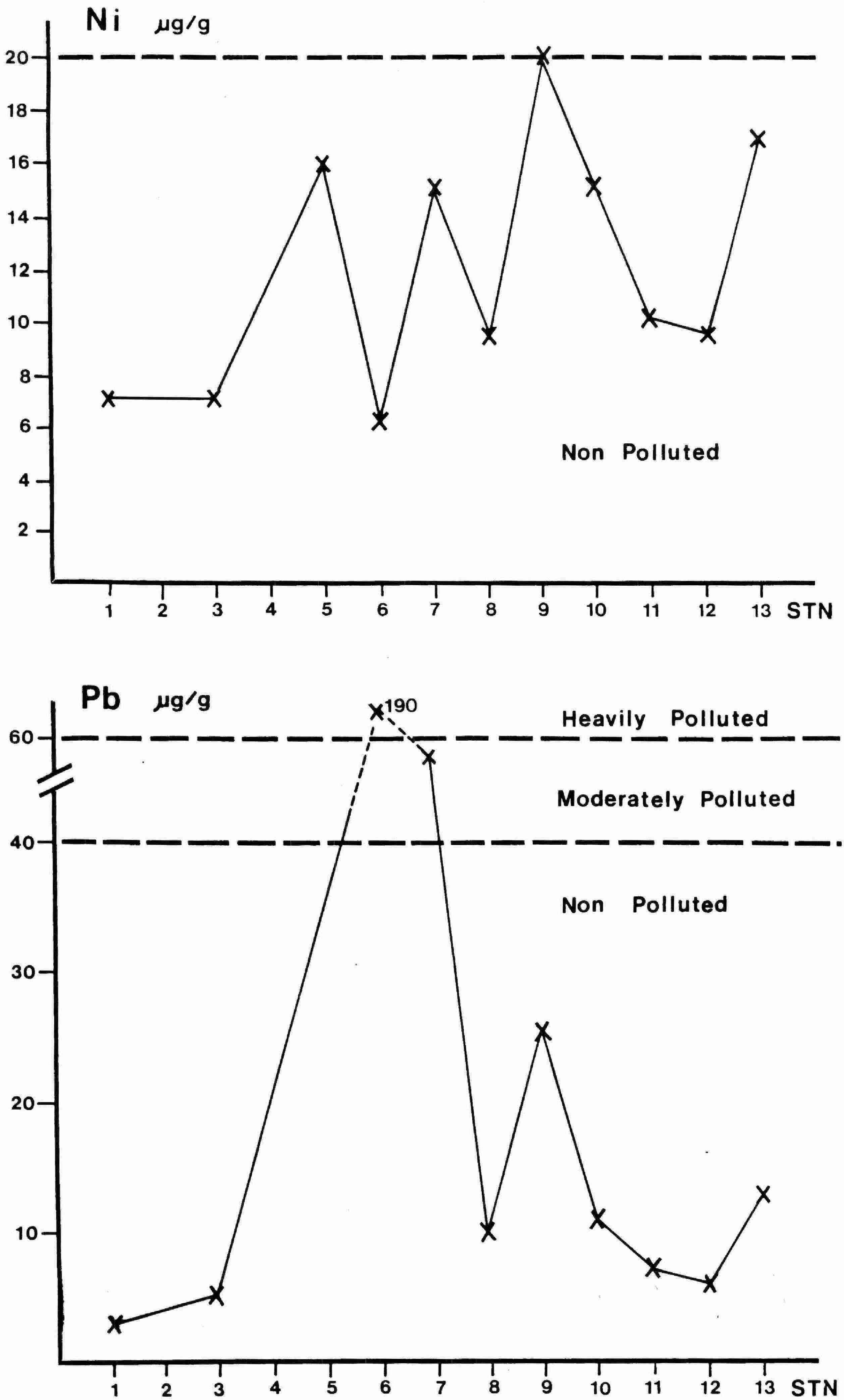
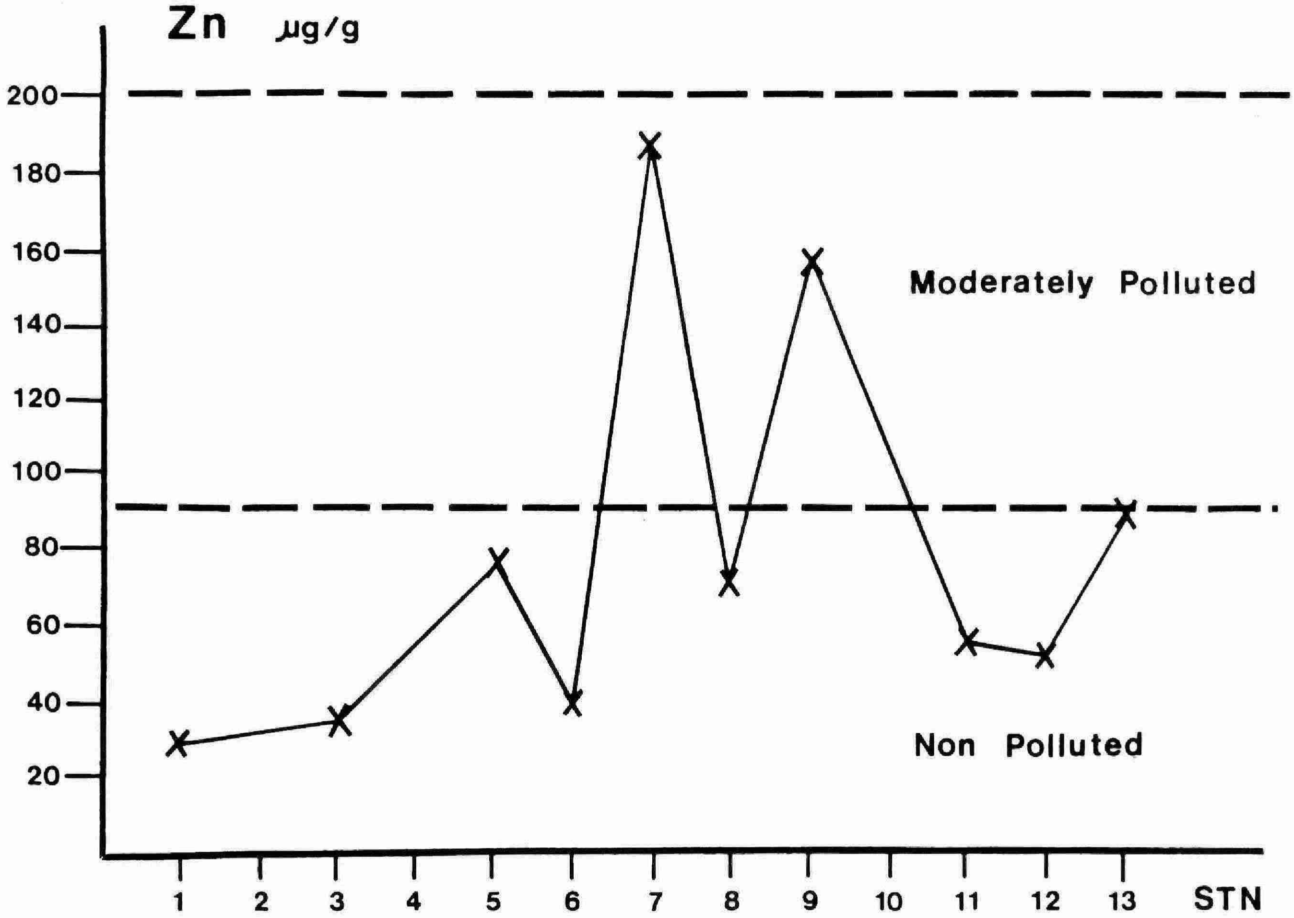


Figure 2 Concentrations of Nickel and Lead in the Avon River Sediment August 6,1980



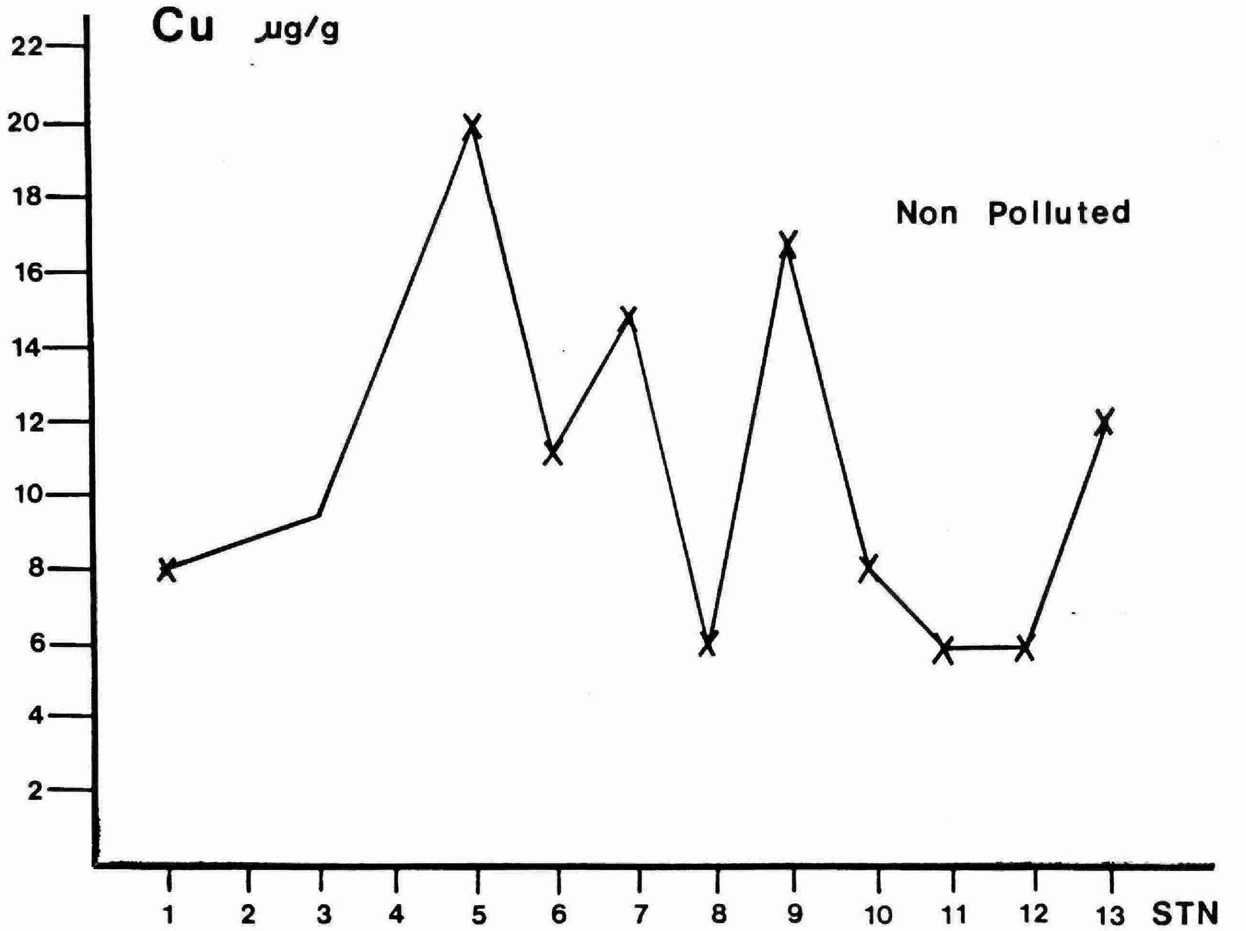
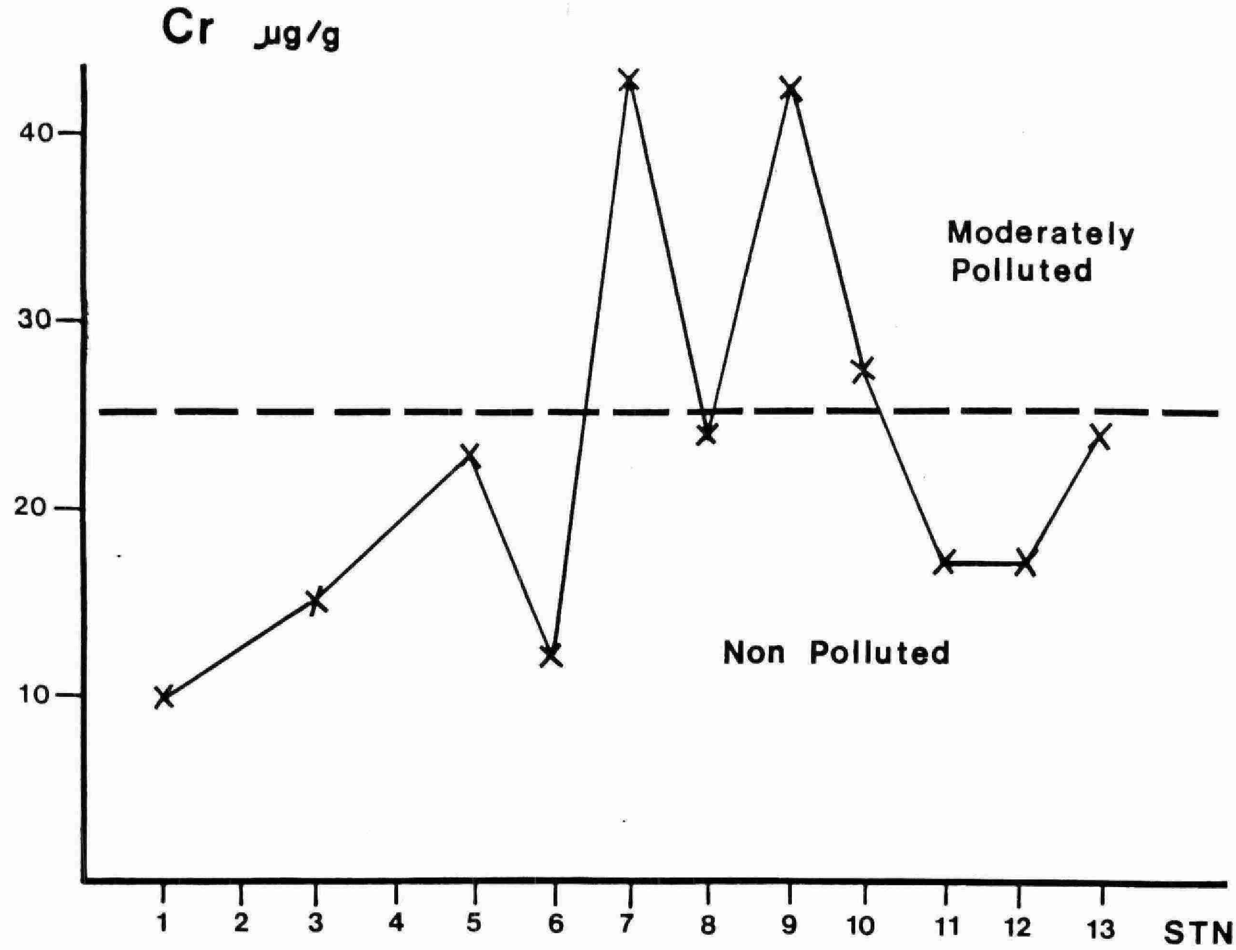


Figure 3 Concentrations of Zinc and Copper in the Avon River Sediment August 6, 1980



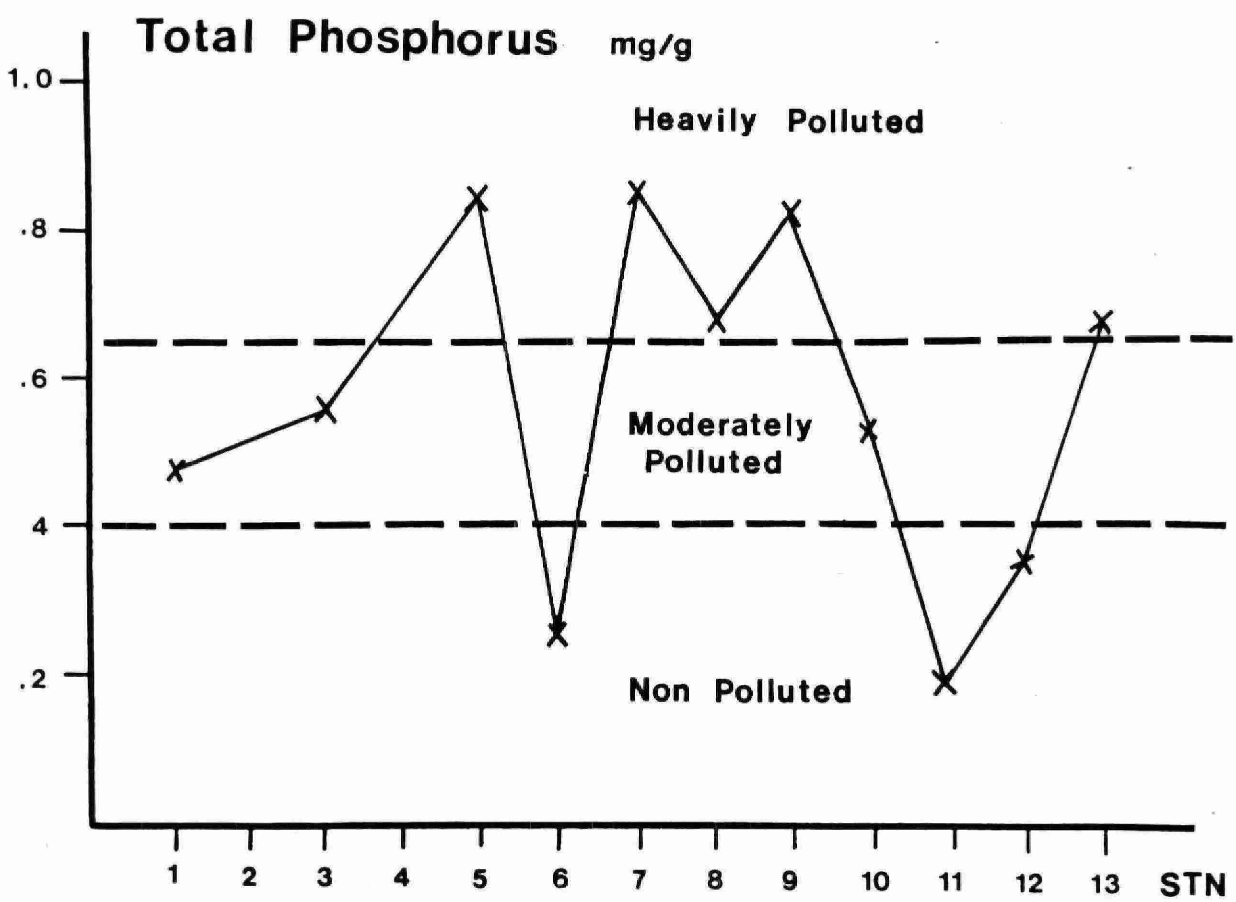


Figure 4 Concentration of Chromium and Total Phosphorus in the Avon River Sediment August 6, 1980

TABLE II: CLASSIFICATION OF GREAT LAKES SEDIMENTS*

		Nonpolluted $\mu g/g$	Moderately Polluted	Heavily Polluted
COD		40,000	40,000-80,000	> 80,000
TKN		1,000	1000-2000	> 2,000
LEAD	Pb	40	40-60	> 60
ZINC	Zn	90	90-200	> 200
MERCURY	Hg	1.0	-	> 1.0
PHOSPHORUS	P	.420	420-650	> 650
IRON	Fe	17,000	17,000-25,000	> 25,000
NICKEL	Ni	20	20-50	> 50
MANGANESE	Mn	300	300-500	> 500
CHROMIUM	Cr	25	25-75	> 75
COPPER	Cu	25	25-50	> 50

*Taken from the Hamilton Harbour Study Report, Lake Systems Unit, Water Modelling Section, Water Resources Branch, Ontario Ministry of the Environment, Toronto, August 1977, p.c-6.

The magnitude of the task of dredging the required sediment volume, coupled with potential problems of contamination and environmental disruption make dredging infeasible.

3.2 Light Reduction

The planting of trees to reduce sunlight, up to 80 % , reaching aquatic plants is both inexpensive and aesthetically pleasing (Fortin and Seto 1982).

Results of plant growth simulations using the ECOL1 model are shown in Figure 5. The simulation results , Figure 5 , indicate that light reduction through shading by trees could have a substantial impact upon the growth of aquatic plants in the Avon River, and thus upon the dissolved oxygen regime. The investigations using the model indicate that the required reduction in light could be as high as 80 % .

A secondary benefit of such a scheme might be the establishment of buffer strips along the river which could result in decreased runoff to the river.

There are two potential problems associated with tree planting along the stream bank. The first is the possible instream dissolved oxygen depletion resulting from the influx and decay of leaves and branches from the trees. This problem is not anticipated to be great since debris from trees would enter the water course in the fall when cool temperatures would prevail against rapid decay. The second problem is the increased potential for spring ice jams and subsequent flooding because of additional trees planted on the previously barren floodplain. Spring ice jams and resulting bankside scouring may impair the establishment of trees since ice scour can inflict severe damage to the seedlings.

3.3 Chemical Control

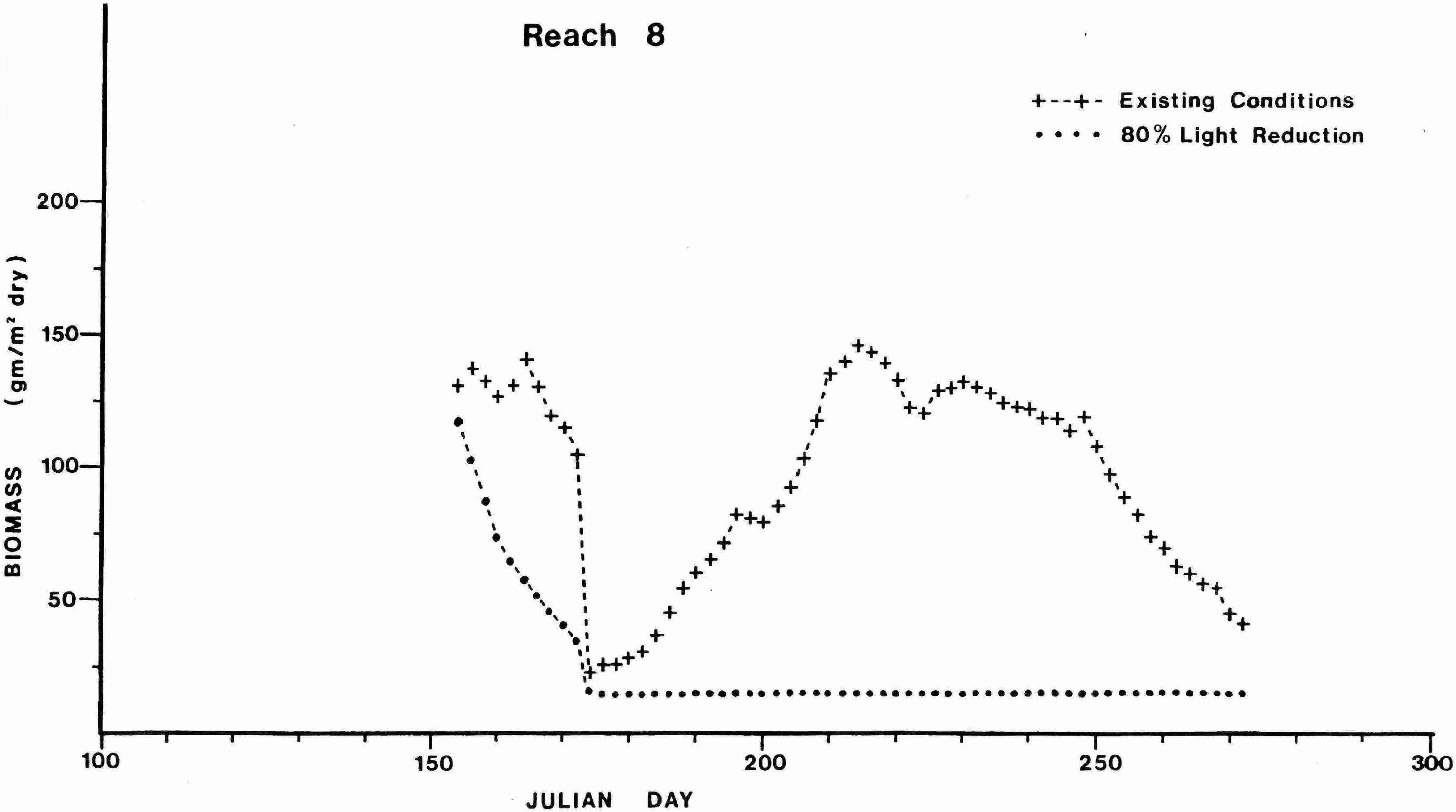
Herbicide application could achieve seasonal control of plant biomass through the introduction of a phyto-toxic substance into the water body. This technique, while providing effective control of the plants, has several major drawbacks which suggest that it may be impractical for the Avon River.

There is no broad-spectrum chemical which will control both filamentous algae (e.g. Cladophora) and rooted aquatics (e.g. Potamogeton). For this reason, a variety of herbicides must be used throughout the growing season to achieve satisfactory results.

FIGURE 5

1980 80% LIGHT REDUCTION

Reach 8



Sufficient contact time must be provided to dose the plants adequately and the herbicide must not be diluted by river flow, so multiple injection sites are required. A third problem is that of serious dissolved oxygen depletion which could result from large masses of decaying plant material. The use of herbicides is also complicated by its potentially toxic effects on livestock, humans and fish downstream of injection (MOE 1980, OMAF 1980). The final costs associated with herbicide injection are not high however. The widely used herbicide Diquat, marketed under the name of Reglone A, presently sells for approximately $70 per litre. Estimated costs of this chemical for a typical season of biomass control on the Avon River are estimated at $12,000 (see Appendix).

3.4 Removal of Aquatics

Results from manual harvesting indicated that cropping could proceed at about approximately 120 square metres of stream bed per person per day if 75% of the existing plant material was removed. Cropping would have to be completed within a week to prevent significant regrowth of plants to nuisance levels during the time taken to crop the entire river. Based on this constraint, manual cropping would require 512 people (5 day work week) to crop the entire Avon River below Stratford. This option is clearly high in cost and is therefore considered impractical for application in the Avon River.

An alternative to manual harvesting is available through mechanical harvesting. There are several machines now available which are suitable for use in lakes; however none are suitable for use in shallow, rocky rivers without modification (Allin 1980). Such modifications (suggested by Allin 1980) include the replacement of paddle-wheel propulsion with amphibious balloon tire propulsion, extensive modifications to cutting bars to allow them to slide up over rocks, and changes to the steering system to allow for the increased manouverability required in a river. Costs for purchase and modifications were estimated at between $225,000 and $665,000 1980 dollars depending upon the machine chosen.

Cropping would be required several times over the growing season to prevent the plants from attaining nuisance densities. The frequency of cropping was determined by simulating the harvesting using the ECOL1 model (Walker et al 1981). The major constraint in the simulations was that cropping was handled in the model as a step reduction once biomass density achieved the nuisance level of 150 gm/m^2 dry weight. The results of the simulation runs assuming 50% and 90% cropping efficiency are shown in Figures 6 and 7 respectively. The results indicate the necessity for 7 croppings with a 50% efficiency and 4 croppings with a 90% efficiency.

A secondary problem of cropping is the disposal of harvested plant material , (as much as 46000 kg. dry wt. total / year). Cropped, decaying plant material looks unsightly and has a foul smell. This makes bank disposal undesirable and favours disposal in a less open area, such as a landfill site. Recent analyses at the University of Guelph feed laboratory indicate that dried aquatic plant material might in fact be usable as feed if diluted and mixed with other feed material such as corn or hay.

4. DISCUSSION AND CONCLUSIONS

Table IV presents the estimated aquatic plant biomass in each reach assuming an average reach density of 150 gm/m^2 dry weight (based on field data obtained in 1980 and 1981; see SAREMP Technical Report No. S-6).

Figure 6

1980 50% CROPPING EFFICIENCY

Reach 8

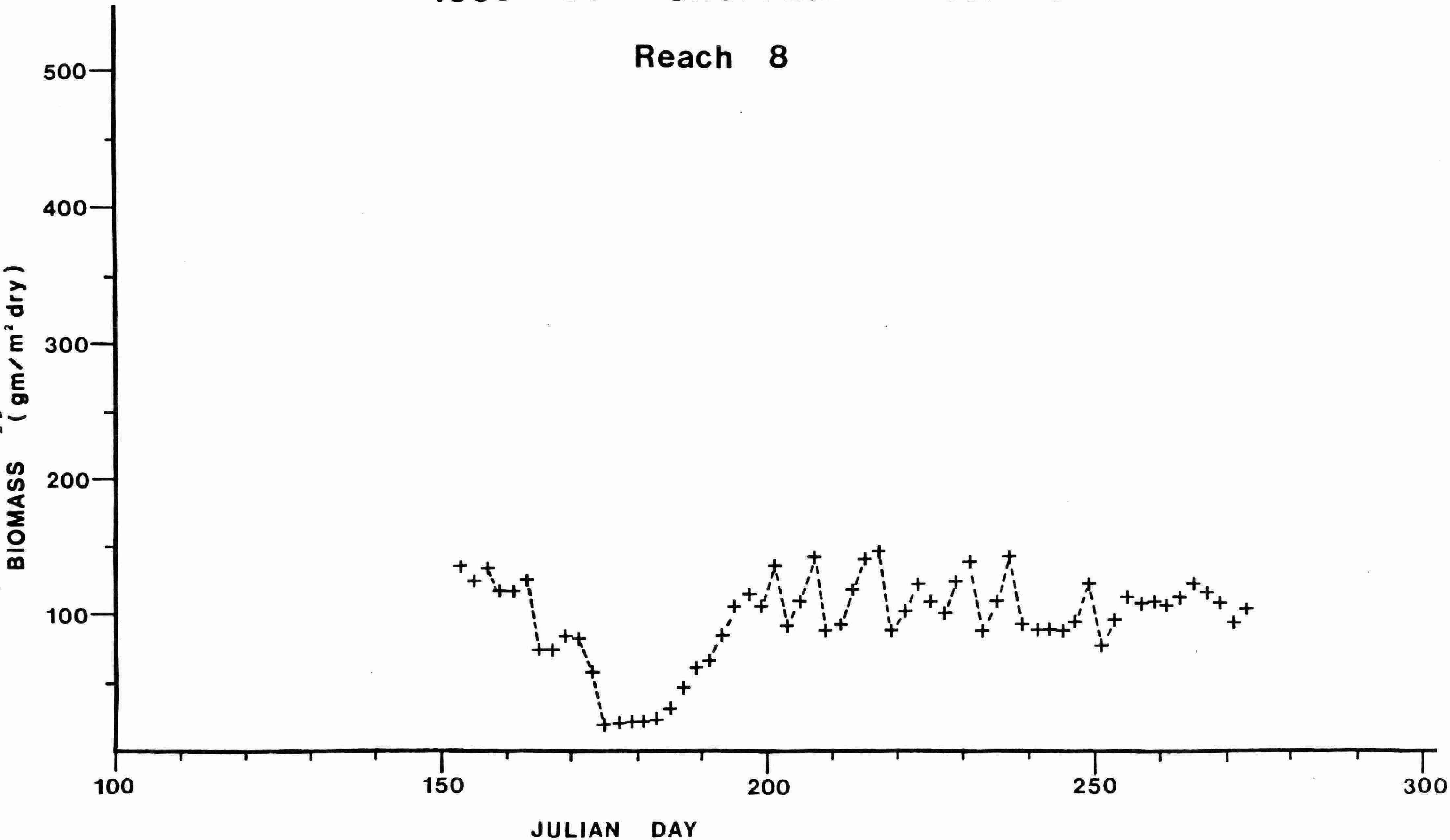


Figure 7

1980 90% CROPPING EFFICIENCY

Reach 8

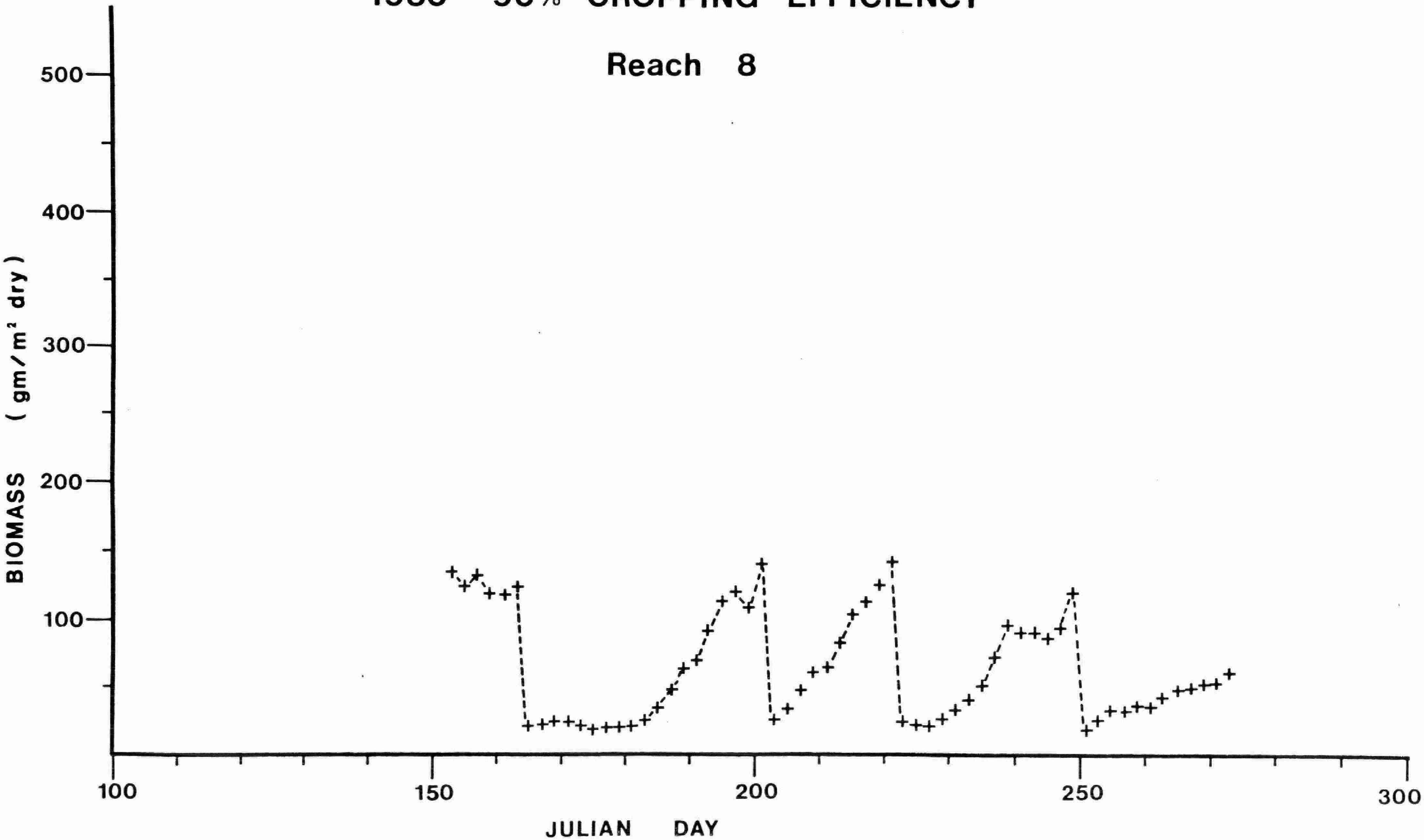


TABLE III: ESTIMATED AQUATIC PLANT DENSITIES IN THE AVON RIVER

Reach	Total Reach Surface Area (m^2)	Plant Biomass (kg dry weight)
1	9602	1440
2	14369	2155
3	48221	7233
4	46011	6901
5	61209	9181
6	37893	5683
7	32799	4919
8	57050	8557
TOTAL	307154	46073

The advantages and disadvantages of several alternative methods for control of aquatic plant growth are presented in Table IV. In assessing each of the alternatives, consideration was given to the potential impacts on the existing stream environment and on water use (for instance, for livestock and irrigation), and to the probable cost of implementing the measure. The most promising option was tree shading; others considered less feasible were mechanical and manual cropping, herbicide injection, increased turbidity, and channelization.

However, these options need not be considered separately. An alternative approach would combine several of the above strategies. For instance, tree shading could be used in areas of the river where the channel is sufficiently narrow (10 metres or less), (Fortin & Seto 1982), to allow the tree canopy to close over the river. In other areas the river channel could be modified by channelization so that an existing machine with a minimum of modifications could be used to crop the aquatic plants.

Some return on capital investment may be realized if harvested plants can be composted and sold as fertilizer or dried and used as livestock feed.

Further investigation into the feasibility and performance of promising control methods, and into the suitablity of plant material for fertilizer, feed, or other uses, will be required before any option for plant control can be implemented.

TABLE IV: ALTERNATIVE METHODS OF BIOMASS CONTROL

Method	Advantages	Disadvantages
Channelization	permanent biomass control	bank failure severe environmental impact
Increase Turbidity	permanent biomass control low cost	water quality is adversely affected aesthetically unappealing
Tree Shading	permanent biomass control barrier strip establishment aesthetically appealing relative low cost	potential leaf litter - DO problem ice jams and flooding difficulty in establishment
Herbicides	no environmental modifications to physical environment relative low cost	seasonal control measure, multiple chemical useage multiple point injection multiple time series applications D.O. depletion from plant decay toxicity
Manual Cropping	minimal environmental disturbances	seasonal control measure labour intensive, high cost, disposal of plants, multiple croppings in year
Mechanical Cropping	minimal labour requirement	seasonal control measure machine availability, high operation and maintenance cost disposal of plants multiple croppings in year

V REFERENCES

Allin, L. 1980. Feasibility Study of Mechanical Harvesting of Aquatic Plants in the Speed River. Ontario Ministry of Agriculture and Food, Foodland Development Branch. Draft.

Bacchus, A. 1981. Physical Characteristics of the Avon River. Stratford Avon River Environmental Management Project Technical Report Series No. S-2.

Draper, D. and R Walker. 1981 Plant Biomass Assessment For Rivers And Streams. Working Group II of the Water Management Steering Committee. Ontario Ministry of the Environment.

Fortin, M., and M. Seto. 1982. Description of an Aboreal Shading Project For the Control of Water Quality. Stratford Avon River Environmental Management Project File Report. Draft.

Ontario Ministry of Agriculture and Food. 1980. Guide to Chemical Weed Control. Publication No. 75.

Ontario Ministry of the Environment. 1980. Aquatic Plant and Algae Control.

Ontario Ministry of the Environment. 1977 Hamilton Harbour Study

Wetzel, R. G. 1975. Liminology. W. B. Saunders Co., Philadelphia.

Walker, R.A. , D.G. Weaterbe, K. Willson 1981 Aquatic Plant Model Derivation and Application. Grand River Basin Water Management Study Technical Report Series No. 14.

Walker, R.A., K. Willson. 1981. Plant Community Assessment Techniques Data Collection and Field Procedures. Grand River Basin Water Management Study Technical Report Series No. 15.

Willson, K., A. Kwong, D. Weatherbe, L. Post. 1981. Water Quality Simulation Models and Modelling Strategy for the Grand River Basin. Grand River Basin Water Management Study Technical Report Series No. 30. Draft.

APPENDIX

ESTIMATED COST OF HERBICIDE INJECTION

1 cfs = 28.317 l/s

Avon River flowing at 10 cfs = 283.17 l/s

herbicide dosage concentration = 1 ppm

1 litre of concentrate must be injected into 10^6 litres of river water

at a flow of 283.17 l/s it takes 3531.45 seconds of river flow to yield 10^6 litres

given a travel time of 5 hr. = 18000 seconds , it requires 5.097 litres of concentrate to dose the entire reach of river

herbicide cost = \$70. per litre

cost for 6 litres = \$420.

if this is done at 7 injection sites (bare minimum) the total cost for the herbicide = 7 x \$420. = \$2940.

add cost of pumps, injection tanks, etc. = \$500.

total cost for 1 dosage of river = \$3440.

estimated 4 applications over growing season

4 x \$3440. = \$13760.

Diquat is a contact herbicide which requires a minimum of 1 hour contact time with the plants at the specified 1 ppm concentration. The herbicide is inactivated by exposure to sunlight , thus the applications must be made at night. Given these constraints it could easily be necessary to double the number of injection sites , thereby increasing the costs to approx. $28000. to dose the river over the growing season. It should be noted that no labour costs are included in these estimates.

STRATFORD-AVON RIVER ENVIRONMENTAL MANAGEMENT PROJECT
LIST OF TECHNICAL REPORTS

- S-1 Impact of Stratford City Impoundments on Water Quality in the Avon River
- S-2 Physical Characteristics of the Avon River
- S-3 Water Quality Monitoring of the Avon River - 1980, 1981
- S-4 Experimental Efforts to Inject Pure Oxygen into the Avon River
- S-5 Experimental Efforts to Aerate the Avon River with Small Instream Dams
- S-6 Growth of Aquatic Plants in the Avon River
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- R-2 Earth Berms and Drop Inlet Structures
- R-3 Demonstration of Improved Livestock and Manure Management Techniques in a Swine operation
- R-4 Identification of Priority Management Areas in the Avon River
- R-5 Occurrence and Control of Soil Erosion and Fluvial Sedimentation in Selected Basins of the Thames River Watershed
- R-6 Open Drain Improvement
- R-7 Grassed Waterway Demonstration Projects
- R-8 The Controlled Access of Livestock to Open Water Courses
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